EEU44C04 / CS4031 / CS7NS3 / EEP55C27
Next Generation Networks

Cognitive Radio

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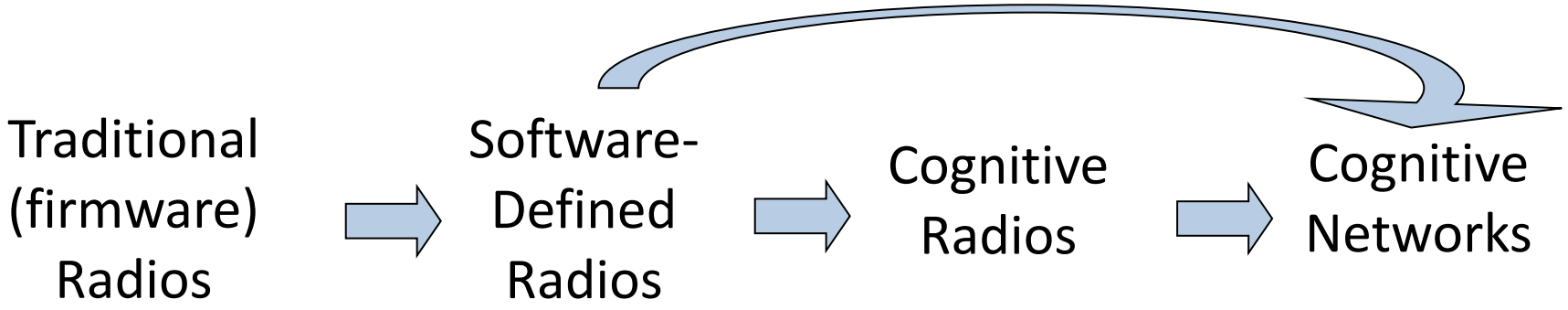
Evolution


Traditional (firmware) Radios
Software-Defined Radios
Cognitive Radios
Cognitive Networks

SDR and cognitive radio

- Software-defined radio (SDR) - a collection of hardware and software technologies that enable reconfigurable system architectures for wireless networks and user terminals (SDR Forum)

- Cognitive radio (CR) – a radio that is aware of and can sense its environment, and can make decisions about its operating behavior based on that information and pre-defined objectives (IEEE 1900.1)

CR - definition (1)

- A transceiver that is aware, adaptive, and capable of learning from experience

… of the RF environment (communication waveform features, propagation channel characteristics)
… of its own capabilities (power consumption, DSP clock rate, device operational status, …)
… of policies it needs to follow
… of local (link) and global (network) objectives
… of network conditions
… of other users' priorities and authorizations

CR - definition (2)

- A transceiver that is aware, adaptive, and capable of learning from experience

… transmit power control
… dynamic waveform selection
… dynamic spectrum access
… block edge masks
… routing
… negotiation of waveforms and protocols

CR - definition (3)

- A transceiver that is aware, adaptive, and capable of learning from experience

… experience-weighted table lookup
… machine learning algorithms

Evolution, revisited

Conventional Radio

- Traditional RF Design
- Traditional Baseband Design

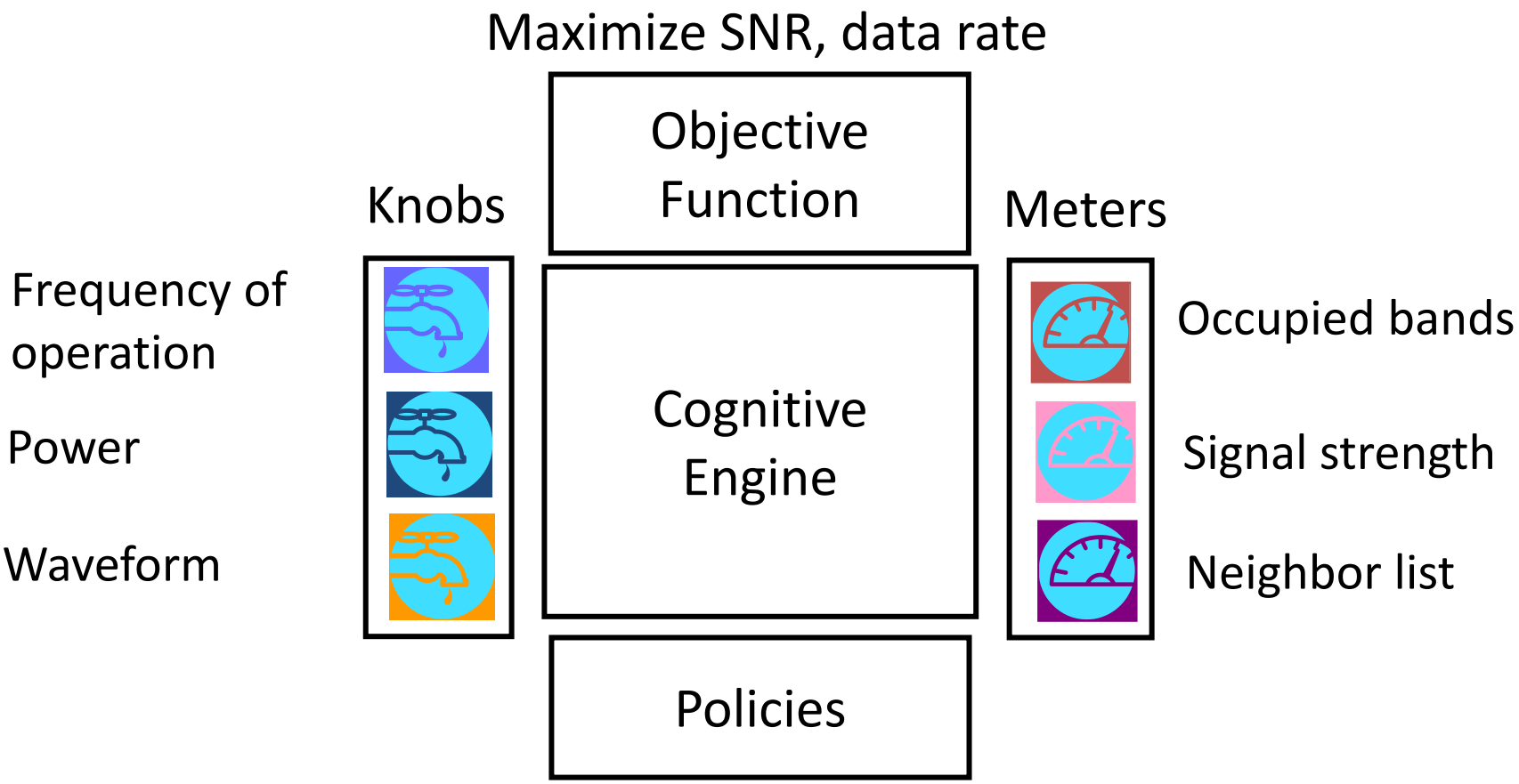
Software Radio

- Conventional Radio
  +
- Software Architecture
- Reconfigurability
- Provisions for easy upgrades

Cognitive Radio

- SDR
  +
- Intelligence
- Awareness
- Learning
- Observations

A cognitive radio

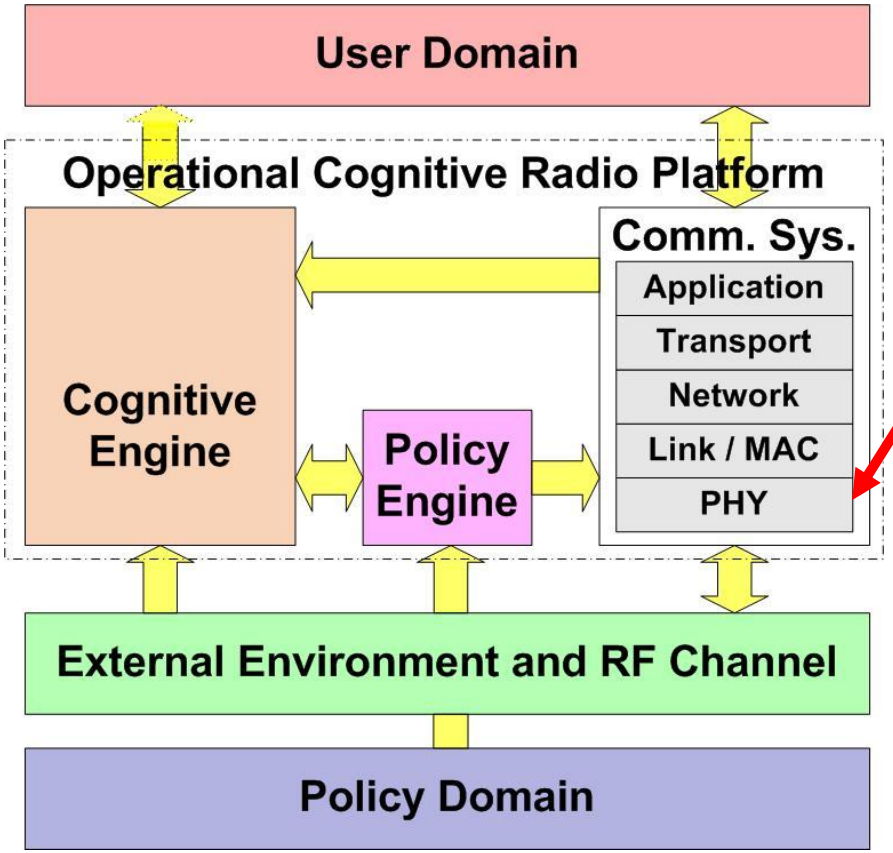


Allowed frequency bands for primary/secondary use (PU/SU)

Desirable features

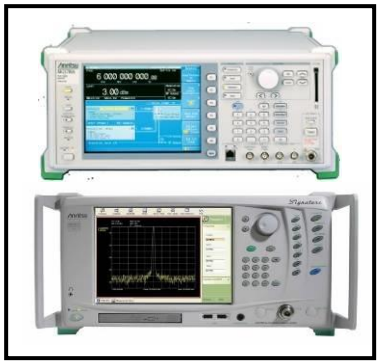
- Wideband
  - "DC to daylight"
- Any waveform
- Flexible architecture
- High performance and low power consumption
- Affordable and accessible
- Relatively straightforward to use and innovate with
- Robust
- Access to suitable frequency spectrum segments for innovation and testing

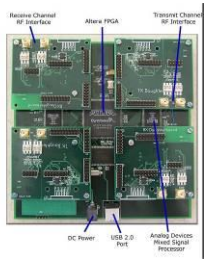
Hardware and software



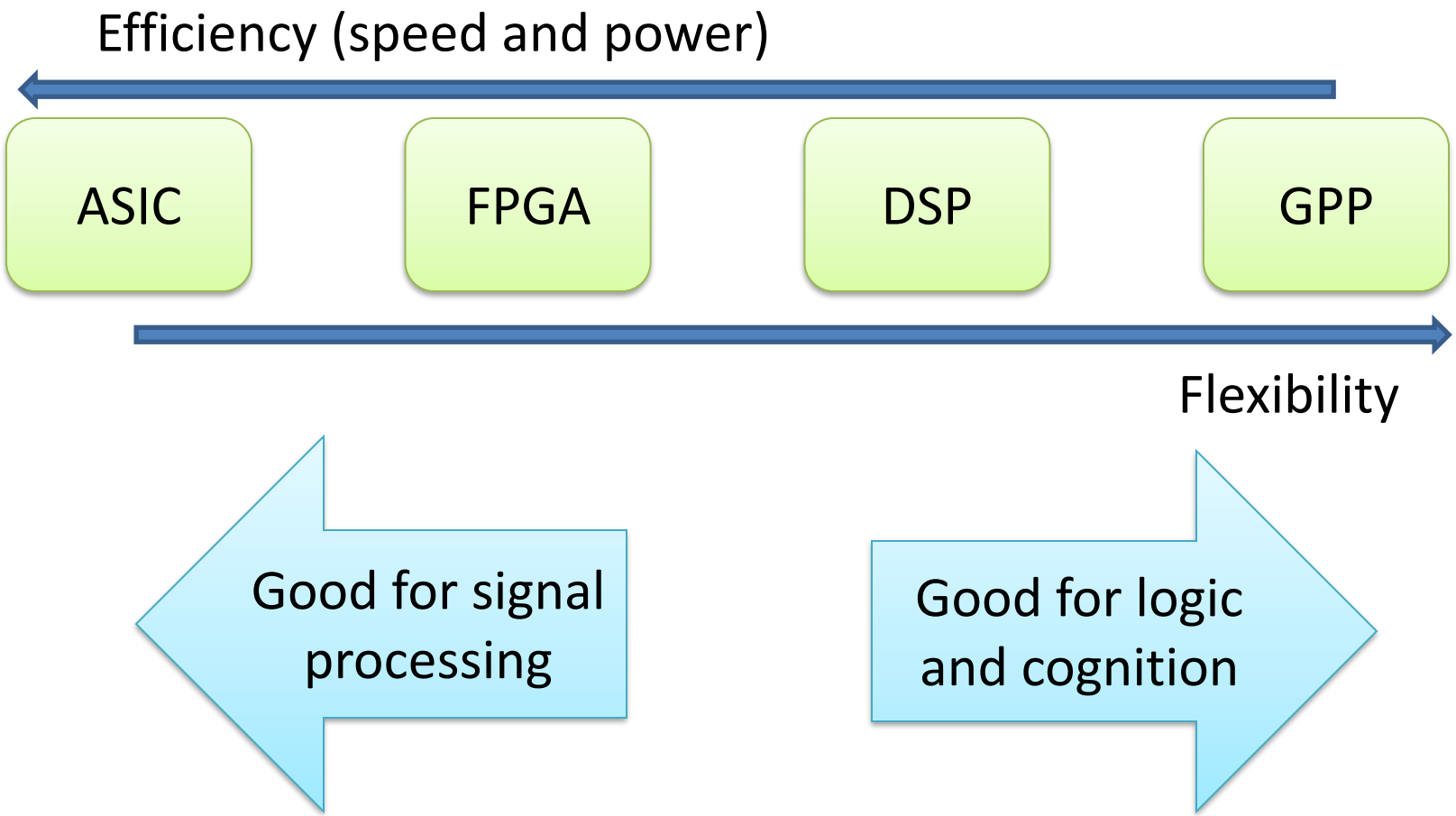
Source: Bostian, 2007

Any SDR can go here

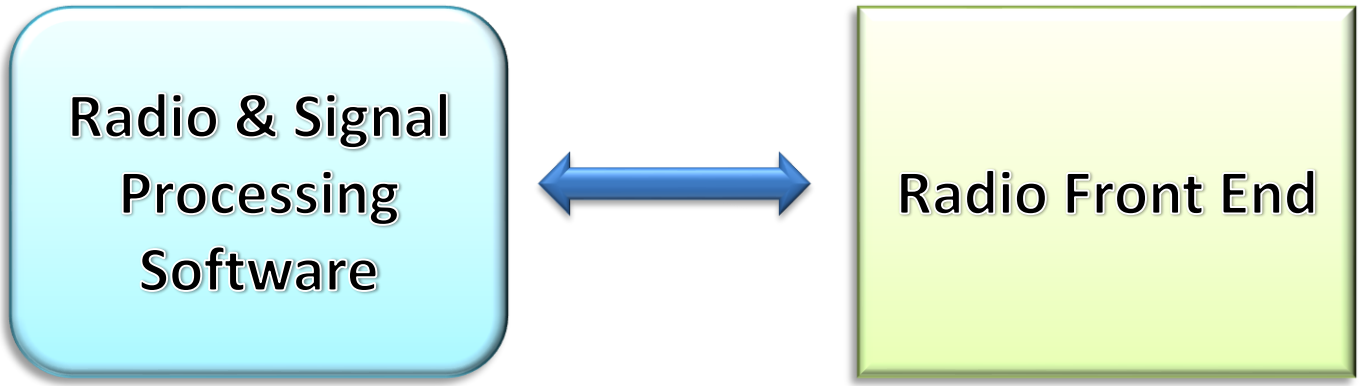




Processing elements tradeoffs



SW/RF front-end separation



Front end deals with frequency, filtering, and power

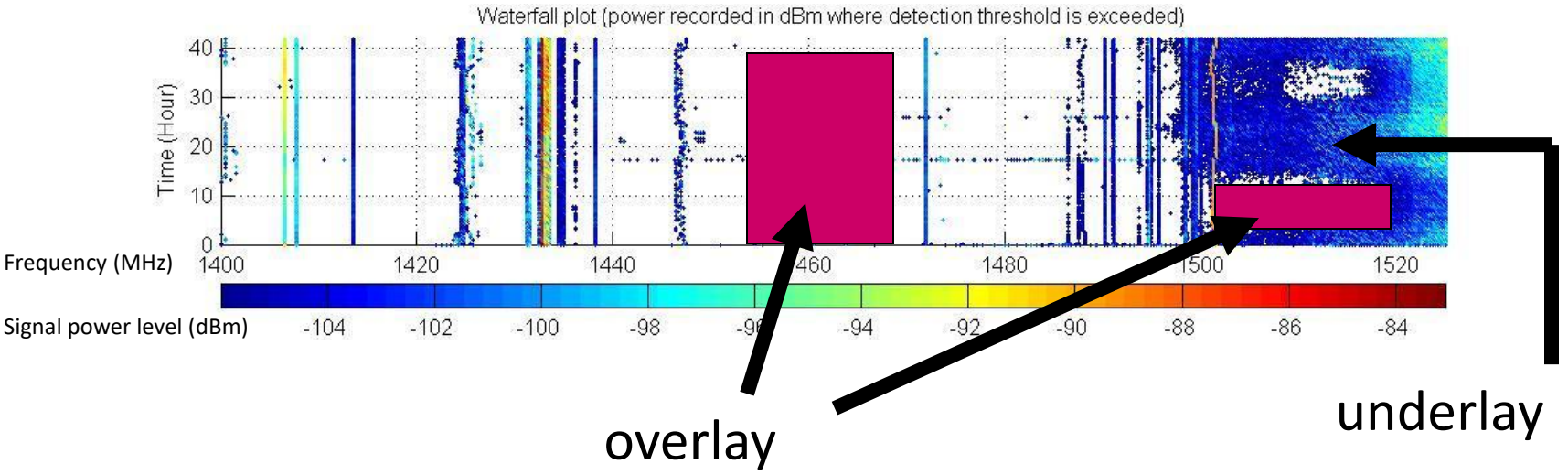
Software handles waveforms and protocols

Cognitive radio applications

- **Dynamic Spectrum Access (DSA)**
- Cooperative medium access and cooperative communications
- Opportunistic switching among available wireless networks (cellular, WLAN, mesh, etc.)
- Adaptive selection of available radio resources (e.g., cognitive MIMO, selection among different waveforms)
- Increased interoperability of different systems (spectrum sharing & sensing → increase spectrum usage & reduce interference)

Spectrum sharing

- Only a small percentage of the spectrum used at any one time
- Why can't we share?
  - **Overlay** – Opportunistic use of fallow spectrum
  - **Underlay** – Non-interfering use



DSA: major players

- IEEE and other standards organizations
- Federal Communications Commission (US), Ofcom (UK), ComReg (Ireland) and regulators around the world
- US Department of Defense (DoD)
- Industry
  - e.g., interest in shared use of spectrum vacated by shift to digital TV

Regulators

- FCC addresses cognitive radios in several Notices of Proposed Rule Making (NPRM)

- Over the past decade, Canada, Japan, South Korea and EU regulators have all been showing interest in more flexible allocation of spectrum

Broadband cellular

- **More bandwidth to increase data rate**
  - Approaches to date have included both increased efficiency (MIMO, more efficient modulation) and piecemeal addition of spectrum (700 MHz)

- Cognitive radio and spectrum brokers
  - Capital intensive to build networks that guarantee coverage and performance ➔
    - save on spectrum if possible
  - Capacity on demand implies DSA ➔
    - flexible data rates ↔ flexible amounts of spectrum

Femtocells

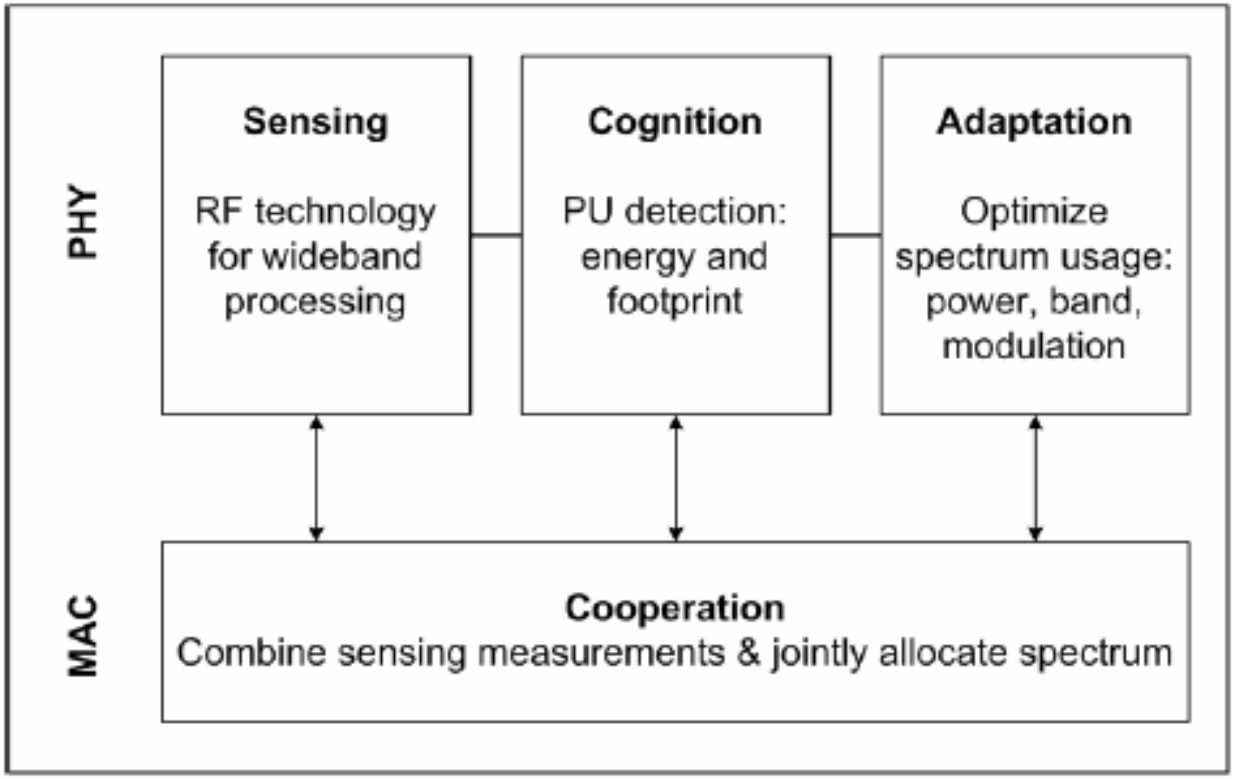
- Small cellular base stations for residential / business installation, sharing 2G/3G/4G/5G spectrum

- Mass market device, so ease of deployment and low price point are major issues
  - Radio planning must be automated: cognitive radios → **self-organizing networks**

Self-organizing networks

- Can automatically extend, change, configure and optimize their topology, coverage, channel allocation and other operating parameters
- Excellent scalability, robustness
- In a sense, prevalent in wired networks at various levels of abstraction
  - Internet, WWW
  - P2P
- **Cognitive radios/networks may self-organization possible in wireless networks**

DSA and cross-layer optimization



Source: Cabric, 2004

PU = Primary User

Cross layer issues

- **Spectrum management**
  - Requires information regarding QoS requirements, transport, routing, scheduling, and sensing
- **Spectrum sharing**
  - Cooperative techniques for *interference mitigation* consider current channel capacity, and may require feedback to/from application
- Spectrum handoff
  - Application, transport, and network layers may be made aware of spectrum mobility
- *Channel-aware* topology control and routing
  - Enables to discriminate if a routing path failed because of traffic congestion, or because of lower layer issues (e.g., fading in PHY layer)

Which one among the following options cannot be considered a cognitive radio "knob"?

- Signal strength
- Frequency of operation
- Power
- Waveform

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